STATUS AND FUTURE OF THE 3D MAFIA GROUP OF CODES

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June 7, 1988

Abstract

The group of fully three dimensional computer codes for solving Maxwell's equations for a wide range of applications, MAFIA, is already well established. Extensive comparisons with measurements have demonstrated the accuracy of the computations. A large number of components have been designed for accelerators, such as kicker magnets, non cylindrical cavities, ferrite loaded cavities, vacuum chambers with slots and transitions, etc. The latest additions to the system include a new static solver that can calculate 3D magneto- and electrostatic fields, and a self consistent version of the 2D-BCI that solves the field equations and the equations of motion in parallel. Work on new eddy current modules has started, which will allow treatment of laminated and/or solid iron cores excited by low frequency currents. Based on our experience with the present releases 1 and 2, we have started a complete revision of the whole user interface and data structure, which will make the codes even more user-friendly and flexible.

Introduction

The acronym MAFIA stands for the solution of **MA**xwell's equations by the **F**inite **I**ntegration **A**lgorithm. This is the name given to a set of fully three-dimensional codes used in the computer-aided design of accelerators. The Finite Integration Technique (FIT) [1,2] produces a first order approximation of Maxwell's equations by replacing the line and surface integrals by mean field values multiplied by path lengths or areas. The algorithm produces a set of matrix equations which can subsequently be solved. The allocation of the field components to the rectangular grid is as shown in Figure 1, with the electric field components allocated at the mid-points of the sides of the rectangular cells and the magnetic field components at the centre of each face, defining a dual grid. As the transition from one cell to the next involves only continuous components, Maxwell's equations are always satisfied at the points of allocation, even when different materials are involved. In addition, the analytical properties of the matrix operators are preserved on the discrete grid [2], in particular $divcurl = 0$, $curlgrad = 0$ which is not necessarily the case for all discretisation methods. Thus after the eigenvalues of the problem are calculated, the numerical results can be tested for their physical correctness and any spurious solutions removed.

Description of the MAFIA Programs

- M3 is the mesh generator used by all programs, which translates the physical problem into mesh data and material distribution data.
- S3 solves three-dimensional electro- and magneto-static problems.
- R3 and E31 (or E32), these two codes, run in sequence, solve Maxwell's equations in the frequency domain. R3 sets up the matrices, adding the material properties and the boundary conditions. E31 is the more accurate eigenvalue solver, which solves the matrix equations and writes the required eigenvectors onto the direct access file. E32 uses advanced multigrid methods and may be used instead of E31 for very large meshes.
- T3 solves Maxwell's equations in the time domain.
- TS3 is a three-dimensional particle-in-cell code, not yet available for public release.
- W3 will solve Maxwell's equations for eddy currents, not yet available for public release.
- A3 will solve dynamic-elastic problems such as sound propagation, projected for future release.
- P3 is the postprocessor for all the codes. Solutions can be displayed graphically and calculations carried out.

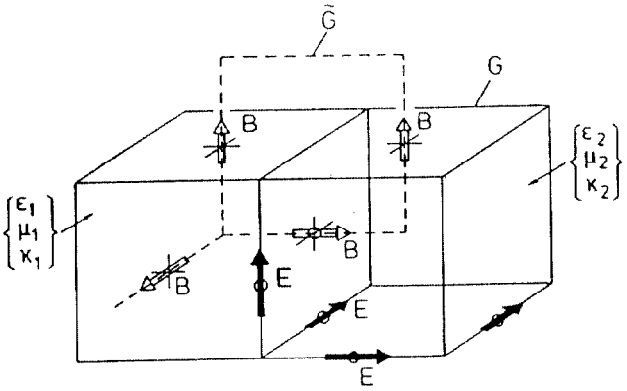

Figure 1: Geometry and Allocation of the Field Components for the FIT [3] Method

Present Status

The second release of the MAFIA Programs, comprising M3, R3, E31, E32 and P3, has been distributed to over 75 installations, including NMFE Computer Center in the United States. The programs have already proved their worth through comparison with theoretical calculations and by successful design of accelerator components. For the third release, the existing MAFIA codes are being completely overhauled and new codes added.

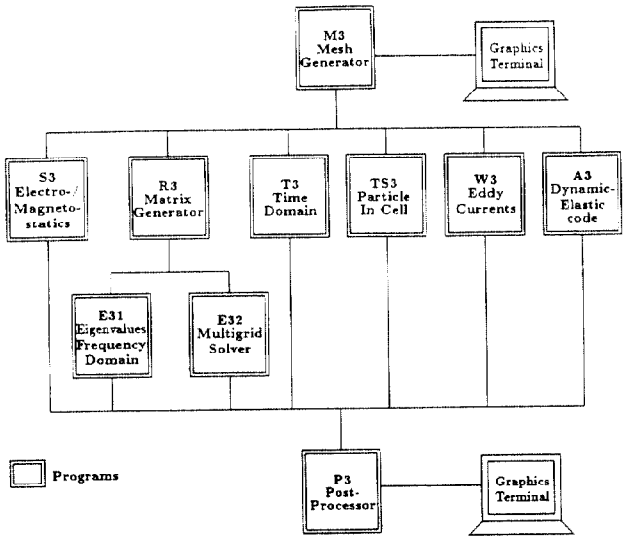

Figure 2: The MAFIA System with its Inter-relationships

Figures 3 to 7 show typical output from the programs. In Figure 3 the MAFIA emblem was modelled by S3. Figure 4 is a hidden line mesh plot from M3. The structure in Figure 5 was a proposed kicker magnet for injection of protons from PETRA into the HERA ring, where the magnet is carried on supports which rotate it into the beam line; however, the computer simulations, using R3-E3, showed that parasitic rf impedances were far too high to ensure a stable beam. Thus this magnet was not built. The arrow plots in Figure 6 show the electric and magnetic fields across the gap of the magnet. Figure 7 shows output from T3.

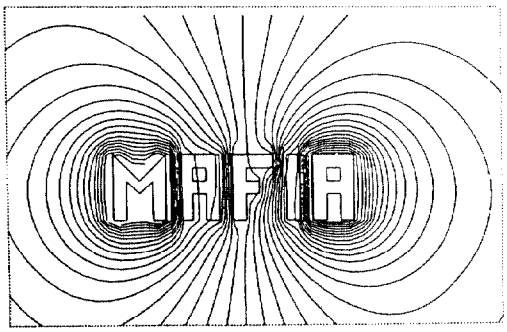

Figure 3: Equipotential plot from S3: first and last letters are metal (electrostatically charged);the three central letters are dielectric.

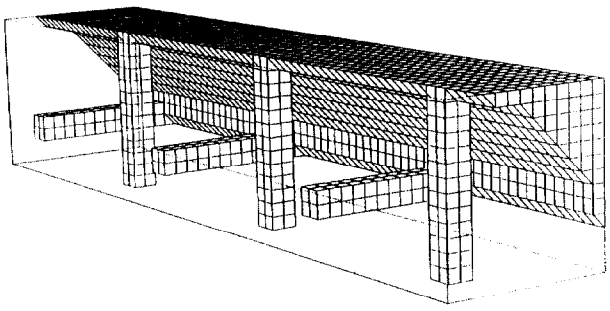

Figure 4: M3 Plot of Geometry and Mesh for the Jungle Gym Accelerating Structure

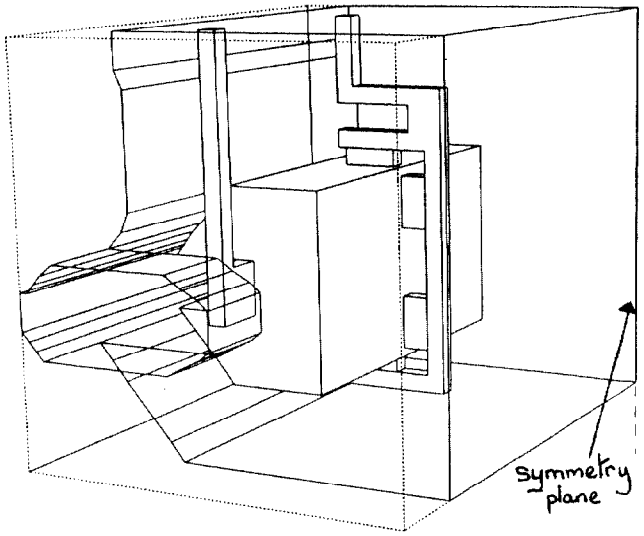

Figure 5: Structure of a Proposed Kicker Magnet for Injection into HERA, (one half of the structure shown)

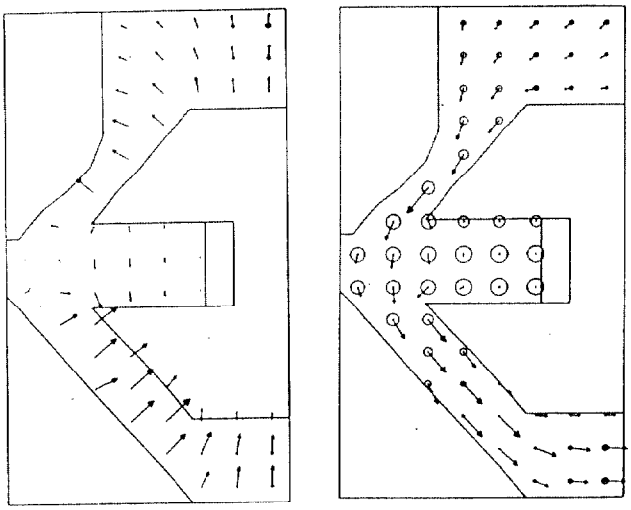

Figure 6: Arrow plots of electric and magnetic field, from E3 - P3 for one of the parasitic rf modes in the kicker magnet(fig.6)

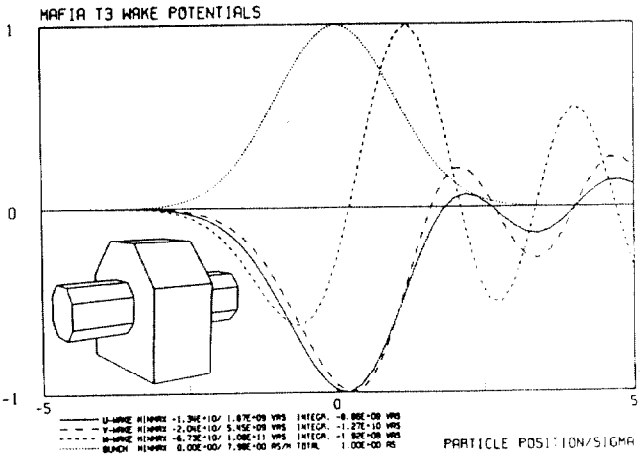

Figure 7: Wakefield Potentials versus bunch coordinates from T3, for the geometry shown in the insert

Features of the New Release of the Programs

- A modular program structure has been adopted.
- A unified, menu-controlled, user interface has been created for all the codes.
- A new command processor has been written.
- The data structure has been changed to accomodate all codes.
- A dynamic memory manager has been added to control both the file and the memory operations.

User Interface

The new user interface is guided by menus. The programs have been restructured and divided into *sections*, each of which represents an independent function of the program, for example, the setting of the mesh or the drawing of an arrow plot. Each section prints a menu which lists all the commands available in that section, with their current settings or default values thus reducing the memorisation of command names. A certain subset of commands, which are desirable to have available at any time, have been selected and called *global* commands. For example, the menu display may be switched off or the file directory printed using a global command.

Help system - The user interface includes a hierarchical help system for the beginning user. The most basic help answers such questions as: - What does this program do? - How do I use it? At any stage of the program the command *help* alone will give advice on how to proceed. A description of the function of each section together with the meaning of the subcommands is also available.

Command Processor

All commands are defined with unabbreviated names. This relieves the user of the task of memorising specific command mnemonics. The command processor is capable of processing shortened versions of these commands; it checks for validity and ambiguity and will accept any unambiguous truncation. More than one command may be entered at a time. A *macro* facility will be included and the command processor will be able to accept predefined macro commands, standing for a string of basic commands. This will enable experienced users to streamline terminal sessions and tailor the program to their particular needs.

Data structure of the direct access file

The new direct access file has a transparent structure with a directory, organised like a database. The storage locations of named fields are recorded in the directory and the user has control of the reading and writing of quantities on the file. The directory is stored and updated in memory and written to the file when the program is terminated. Much general information stored on the file, such as the number of mesh points and the boundary conditions, are stored in readable form so that they can be listed on request from inside the program. It will be possible to allocate, open and close direct access files from within the MAFIA programs.

Dynamic Memory Manager

One of the aims of the new file structure and memory manager is to provide the maximum flexibility in the use of available memory. A combination of selective loading of quantities from the file and of selective deletion in memory of whatever is not needed for a particular operation, can make optimum use of the space available. A load section is provided, where the normal file and memory operations, e.g. get, replace, delete, compress etc., can be invoked. However caution is advised - any precious file should be copied before processing begins.

Mathematical Operations

Many users found that further calculations were necessary to adapt the quantities calculated by P3 to their needs. Such quantities will now be programmed at the level of the individual mathematical operations. This facility will also be made available to the user. It will be possible, for example, to load a field from one direct access file, load the corresponding field from a file with the same mesh but slightly different geometry, difference the two and display the result graphically or perform further calculations as needed. This can be a very powerful tool in the design of accelerators and will enable the codes to be used more creatively. However this freedom also brings certain dangers and the full responsibility for the physical correctness and interpretation of the results lies with the user.

Availability

The MAFIA codes are written in standard Fortran 77 and currently run on IBM 3081, CRAY, VAX and Apollo computers among others. The distribution centre for the codes is DESY, and the codes are available without charge to all non-profit organisations. For information contact T. Weiland at DESY.

Conclusion

Many new features will be added to the MAFIA group of codes. The additional programs will extend the scope of the codes while the new command processor, the conscious file manipulations and the additional calculations that will be possible, will be the features affecting users most directly. However the underlying restructuring of the programs themselves enables a much more efficient management of the support of the codes and is flexible enough to accomodate virtually any future extensions. The newest release of the MAFIA codes will be more user friendly than before, while the new flexibility will allow users to adapt it to their own particular needs.

References

[1] T.Weiland, On the Numerical Solution of Maxwell's Equations and Applications in the Field of Accelerator Physics. Particle Accelerators 15 (1984) , pp.245-292 and references therein

[2] T.Weiland, On the Unique Solution of Maxwellian Eigenvalue problems in Three Dimensions. Particle Accelerators 17 (1985), pp.227-242

[3] K.S.Yee, Numerical Solution of Infinite Boundary Value Problems involving Maxwell's Equations in Isotropic Media. IEEE, AP-14, 1966, pp.302-307.

[4] MAFIA User Guide, The Mafia Collaboration, DESY, Los Alamos National Laboratory, KFA-Jülich February 23, 1987